HIGHLIGHT REMOVAL FROM EXTREMOPHILE IMAGES. I. N. Sandjaja[1], R. J. Marks II[2] and K. E. Schubert[3], [1]Dept. Electrical and Computer Engineering, Baylor University, One Bear Place #97356. iwan_sandjaja@baylor.edu, [2]Dept. Electrical and Computer Engineering, Baylor University, One Bear Place #97356. robert_marks@baylor.edu, [3]Dept. Electrical and Computer Engineering, Baylor University, One Bear Place #97356. keith_schubert @baylor.edu .

Introduction: Cave extreme environment is secluded and protected from outside environments such as weather condition and large animal activity which provides an excellent environment for microbiological system and communities to form pattern that persist over time even with limited resources [1]. The pattern is often etched on the caves' wall leaving the evidence of life that remain long after the life died. To acquire digital images of this evidence of life, several problems are encountered such as limited space, lack of proper lighting, and uneven ground. All this limitation will be also encountered when a robot is sent to a cave on Mars[2].

A single directed light source that is pointed in the same direction as the camera is used in most cases due to the space limitation. The images acquired by this process contains many specular highlights, such as glare, and is worse in dark environments than well-lit ones. This highlight is inevitable due to the surface shape, moisture, and light source characteristics. The specular highlight will destroy the details of the image and creates small glare noises as shown on the Figure 1. In this paper, we will focus on pre-processing image to separate the highlight from extremophile images taken in a cave with single light source.

Highlight Removal: Highlight removal is also well known as specularity filtering or glare separation [3]. In this process, the image is separated into its intrinsic component specifically diffuse and specular reflection component. Highlight can be seen as a specular component that changes the appearance of a surface. Extremophile images from cave environments with specular highlights lose some of its details and have dark shadows that create noise and regional data loss for image processing. Decomposing an image to its diffuse and specular reflection, in general, is an ill-defined problem because there are more unknown variables than the equations, but this is even more difficult in a caves, where limited lighting exists.

We present a new region based algorithm utilizing color space and neighboring characteristics to preserve biopatterns while removing specular noise. First, we convert an image into its color space, to analyze the distribution of the diffuse and specular components for each pixel. Pixels are grouped in neighborhoods and the distribution of diffuse and specular components together with pixel saturation are used to remove the highlight from an extremophile image.

Figure 1: *Example of extremophile image with a specular highlight. The center is of specular highlight is zoomed to show the small glare noise and how the highlight destroy some of the details.*

We compare our method to several states of the art highlight removal methods: Specular Highlight Removal method of Yang et al. [4], the PDE approach [5], Inpainting techniques [6], and manual removal. The extremophile images used in the comparison are from several expeditions with different lighting condition.

Summary: Comparing and developing highlight removal algorithm from extremophile images that are taken in caves would increase the accuracy of image processing and discerning the rule of extremophile more precisely in answering the challenges of exploring extant life on ancient rock record on Earth's caves and on modern Martian caves.

References: [1] Boston, P.J., et al (2015) *Proc. of 2nd International Planetary Caves Conference*, 9028 [2] Schubert, et. al. (2017) *Proc. of 2017 6th International Conference on Space Mission Challenges for Information Technology*, 33-37 [3] Artusi, A., et. al. (2011) Computer Graphics Forum, 30, 2208-2230 [4] Yang, Q., et. al (2015) *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 37, 6, 1304-1311. [5] Mallick S. P. et. al., (2006) *Proc. of the European Conference on Computer Vision*, vol. 3951, 550-563, [6] Tan P. et. al. (2006) *Proc of IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, vol 2, 1855-1960